Impact of emerging WDM technology on high-performance system interconnects

Exploiting the wavelength dimension to provide

More computation in smaller spaces

Want "*More brains, less brawn*"

Logic, memory, and memory access

weight, size, power, copper, batteries, ...

Tony Levi, University of Southern California
alevi@usc.edu

Clay Hudgins, Harris Corporation — Communications Systems Division
chudgins@harris.com

Dave Dolfi, Agilent Technologies
dave_dolfi@agilent.com

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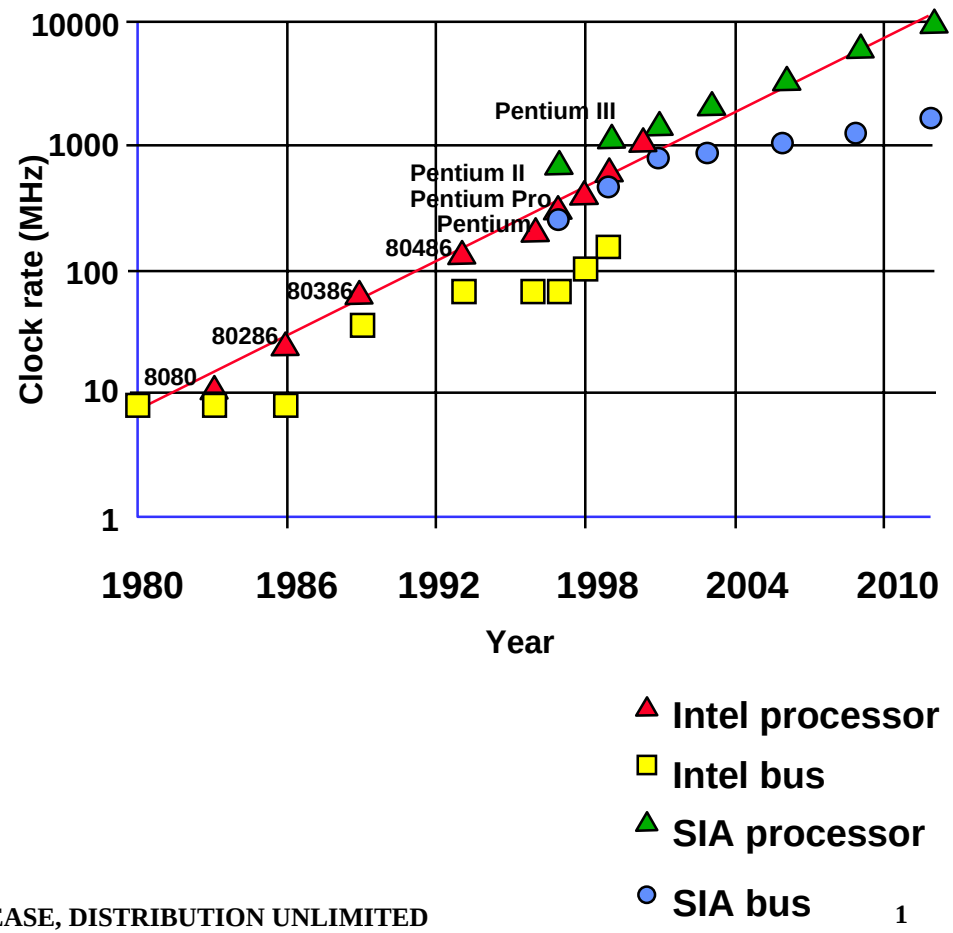
Key questions

and preliminary answers

- **What does WDM provide?**
  - Another dimension of freedom in system design
- **Where should we look for big payoffs?**
  - All networked systems
  - Mobile systems
  - Micro systems
- **What are the ultimate goals?**
  - Provide capability to leapfrog incremental system improvements
  - Optimal information distribution
  - Real-time collaborative decision making
  - Military need to push algorithms and appropriate decision making out of the back-office and into the field

- **What drives network traffic?**
  - Processor advances



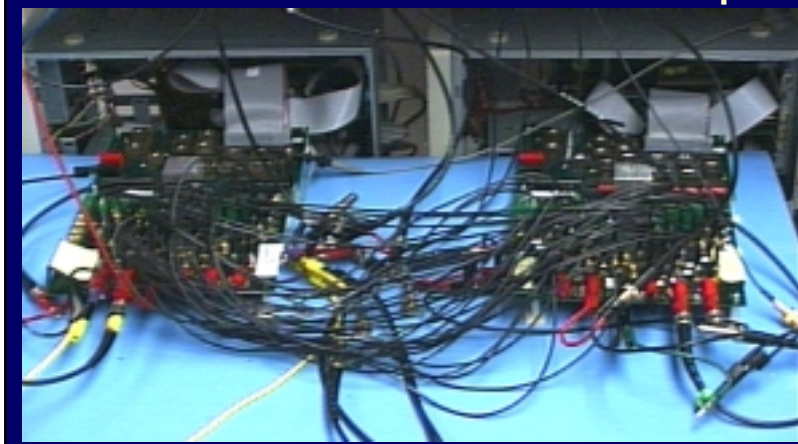
Key questions

and preliminary answers

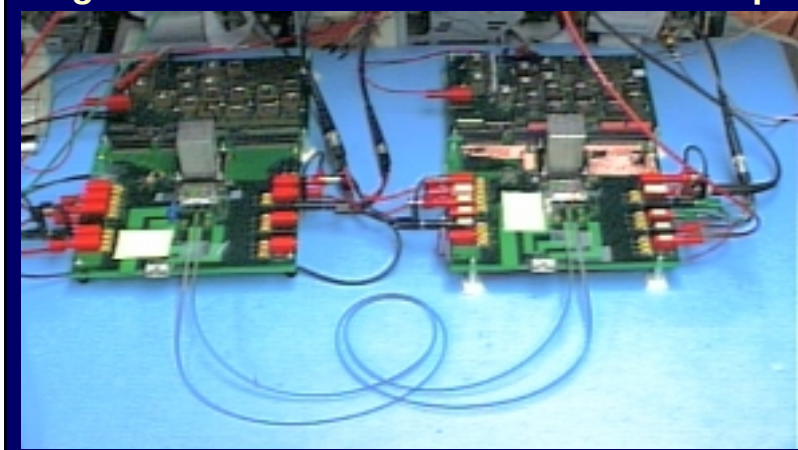
- **What is needed to achieve goals?**
  - **More computations per unit {size • weight • power}**
  - **More *"brains per unit brawn"***
- **What's holding us back today**
  - ***Not enough chip-level I/O to keep transistors busy***
  - **PCB technology stressed by 1000+ chip I/O**
    - **stacked micro-vias**
  - **Lack of commercial investment**
    - **WDM technology focused on long-haul telecommunications systems**
    - **Data-communications investment focused on squeezing "just a little more" out of copper**

Example:
USC PONI-ROPE PCB area < 50%
ICs, surface mount packages,
12-metal layers, Gb/s per signal line,
de-skewed signal lines to +/- 10 ps,
5 mil lines, 7 mil spaces

Electrical test fixture for USC LA chip



Agilent POLO-2 module and USC LA chip

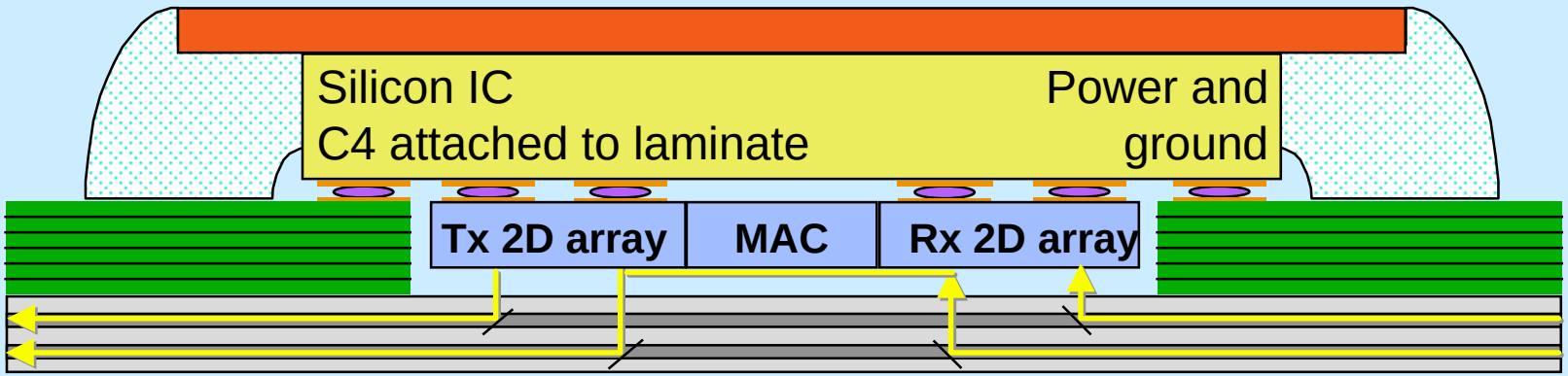


Key questions

and preliminary answers

- **Where is the commercial technology going in three years?**
  - Low-voltage differential signaling at Gb/s rates
  - Ubiquitous 1000+ chip I/O packaging
  - Exotic PCB technology
  - *Preparing for incremental improvements*
- **What is DARPA's opportunity over three to five years?**
  - Focus on efficient inter- and intra-PCB interconnect
  - Nano-photonic components for wavelength-routed 10 Gb/s per line system interconnect
  - *Leapfrog incremental improvements and provide components for new system optimization*

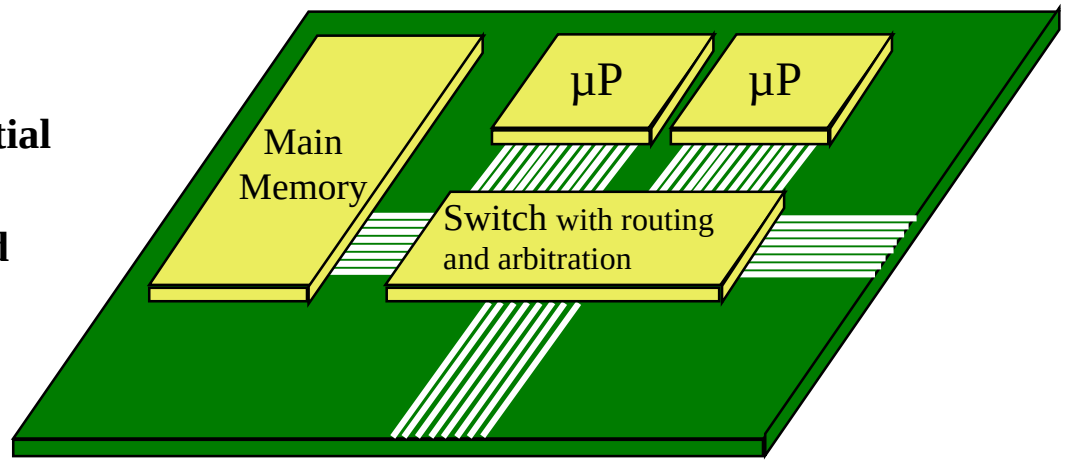
Future heterogeneous integration of photonic Media Access Control



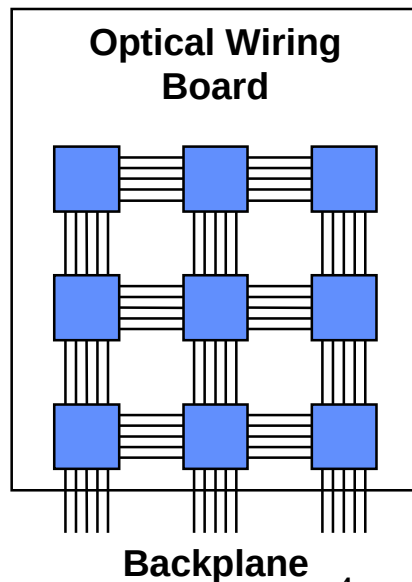
WDM for inter- and intra-PCB interconnects

- **Concept**
  - Topologically simple chip-to-chip optical interconnects
  - WDM to compete with Cu for spatial density
  - Complex logical topologies created by switching in silicon
- **WDM provides**
  - Improved data-bandwidth density compared to TDM or spatial multiplexing
  - Lower-cost connector compared to parallel fiber-optic solution
  - Future use of integrated nano-photonic components for all-optical functions

Multi-processor node 10x10 cm²



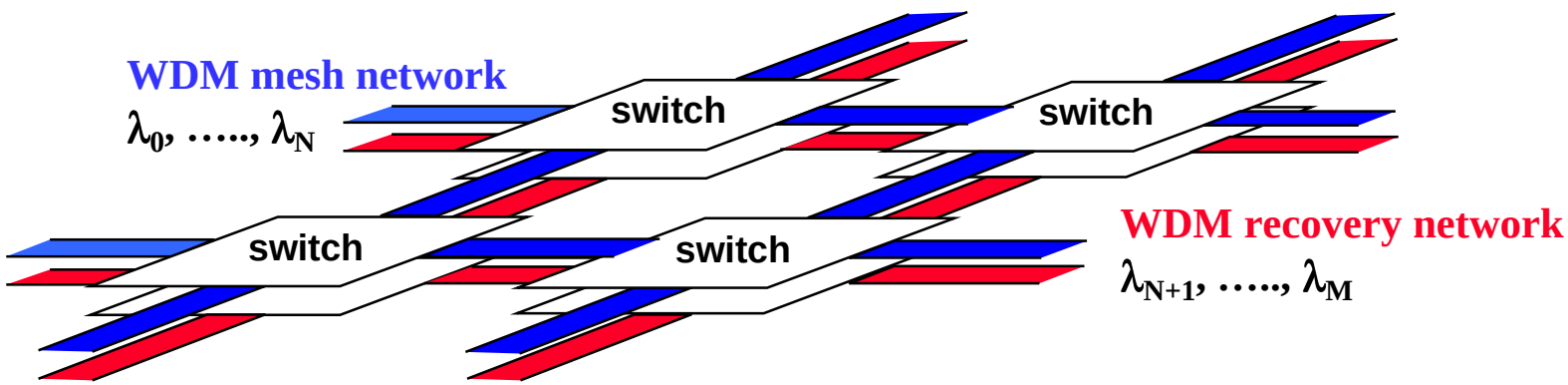
- **Ideal network router**
  - Non-blocking connectivity
  - Speed-of-light latency
  - Infinite-bandwidth



Wavelength routed system interconnect

Solves congestion problems in networks

- **Deadlock kills switched systems**
  - Switched systems implement algorithms that *avoid* deadlock because of its impact on performance
  - Conventional solution prevents packets from entering the network
    - Packet discard
    - Flow control with back-pressure feedback using dedicated lines to stop transmission until receiver is ready
    - Choke packet warning returned to source on switch overload. Source reduces its traffic by a percentage amount
- **WDM can provide an efficient recovery mechanism**
  - Overlay a wavelength-configurable interconnect onto a topologically simple system interconnect
  - Route incoming data to empty buffers in congestion free-part of the network
- **Simple physical topological**
  - Logically discrete channels
  - Efficient distribution of global system parameters



Summary

- **Time Division and Space Division Multiplexing have been exploited**
- **Wavelength Division Multiplexing**
  - **Provides additional dimension for system design**
  - **Important new tool for achieving more "*brains per unit brawn*" in aerospace and mobile systems**
  - **Successfully implemented in long-haul telecommunication systems**
  - **Migration to small systems enabled by**
    - **Nano-photonics**
    - **Innovative packaging and integration**
- **The promise of WDM optics**
  - **"Free, infinite-bandwidth density, anywhere, anytime !"**
- **DARPA involvement provides focus on**
  - **Integrated CMOS-based opto-electronics *inside* systems**
  - **WDM micro-photonic functionality *inside* systems**